# Risk and Sustainability: Assessing Resource Management Procedures

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# Issue

- Sustainable management of fisheries under risk
  - Multi-criteria analysis (economic, ecological and social objectives)
  - Optimality vs. assessment of practical management procedures
  - Dealing with time (long-run and dynamics) and uncertainty

Charles (1998) Fisheries Research

# Literature (1/2)
# Optimal fishery management under risk in the economic literature

- Economic literature:
  - Reed (1979) JEEM
  - Clark & Kirkwood (1986) JEEM
  - Danielsson (2002) JEEM
  - Sethi, Costello, Fisher, Hanemann (2005) JEEM

# Economic approach

- The usual approach:
  - Stylized models
  - Optimal control with a unique economic criterion (discounted expected profit, harvest or utility)

$$\max_{\{q_t\}\geqslant 0} \quad \mathbb{E}\left\{\sum_{0}^{\infty} \alpha^t h_t\right\}$$

$$\begin{aligned} \text{s.t.} \quad & x_t = z_t^{\mathrm{g}} G(s_{t-1}), \\ & s_t = x_t - h_t, \\ & m_t = z_t^{\mathrm{m}} x_t, \\ & h_t = \min(x_t, z_t^{\mathrm{i}} q_t) \end{aligned}$$

The optimal feedback is hard to compute, and could hardly be applied in practice.

# Literature (2/2)
# Management Strategy Evaluation

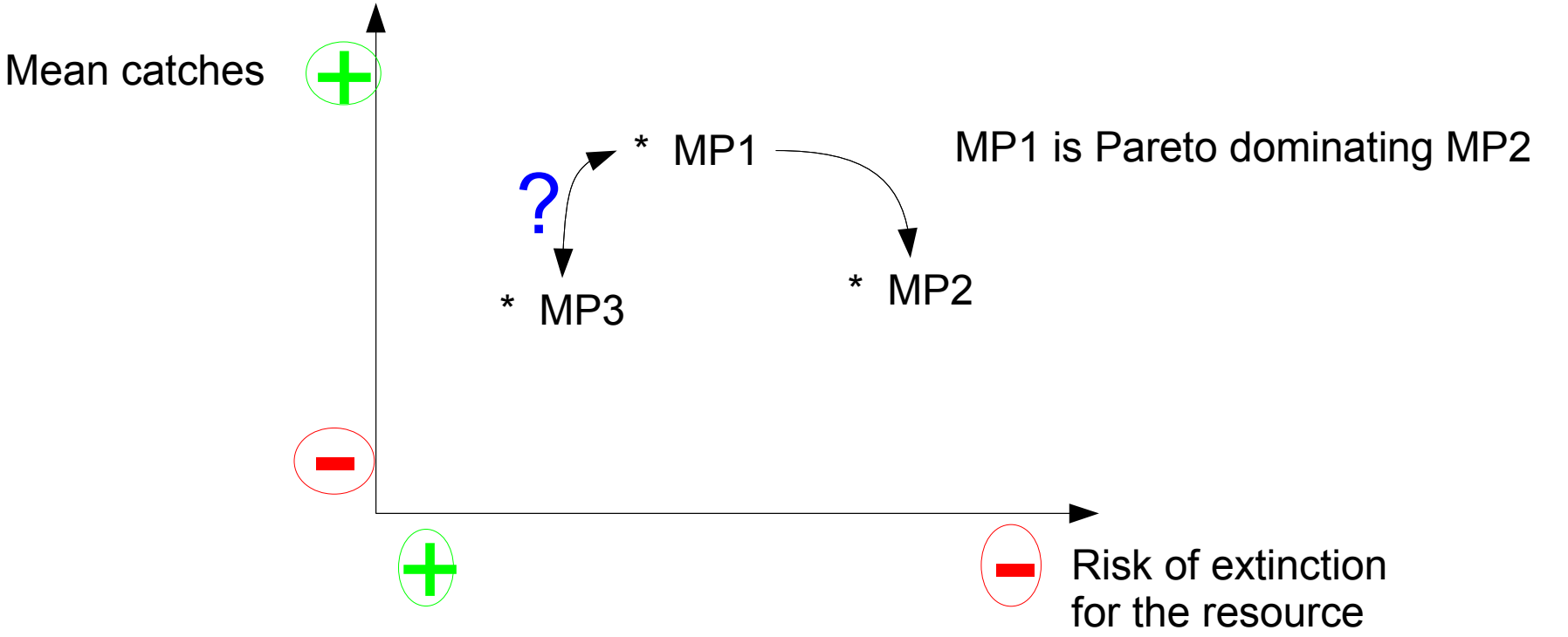
- Fisheries management literature
  - Butterworth, Cochrane & De Oliveira (1997) ICES JMSc
  - Geromont, De Oliveira, et al (1999) ICES JMSc
  - Saintsbury, Punt & Smith (2000) ICES JMSc
  - De Oliveira & Butterworth (2004) ICES JMSc
  - Fletcher (2005) ICES JMSc
  - Kell et al. (2005) ICES JMSc
  - Smith, Fulton et al (2007) ICES JMSc

# Fisheries Management Literature

- The MSE approach:

Realistic models; Simulation under uncertainty; Assessment of management procedures; Multicriteria analysis

- Present the outcome of management procedures but do not rank them



# Purpose of the paper

- To provide a theoretical framework to define optimal management strategies from a multi-criteria objective perspective
- To provide a practical framework to assess management procedures
- To describe the trade-offs between sustainability objectives in fisheries management, with environmental uncertainties

# The stochastic viability approach

- Viability approach
  - Various sustainability objectives defined as viability constraints
  - Definition of viable decisions rules resulting in a trajectories which satisfy all the constraints over time
- Viable Strategy Evaluation:
  - Viability probability: probability that there are viable decisions
  - MP that maximizes the viability probability

# Viability literature

- Aubin (1991) Springer
- Béné, Doyen & Gabay (2001) Ecol. Econ.

- Doyen, De Lara, Ferraris & Pelletier (2007) Ecol. Modelling
- De Lara & Doyen (2008) Springer

# Stochastic viability

- Formal model $x(t+1) = G\big(t, x(t), u(t), \omega(t)\big)$
- Decision rule $u(t) = \widehat{u}(t,x) \in \mathbb{U}$
- Uncertainty scenario $\Omega := \mathbb{W}^{T-t_0}$

as the set of *scenarios*, the notation[4] for a scenario being

$$\omega(\cdot) := \big(\omega(t_0), \ldots, \omega(T-1)\big) .$$

- Viability constraints: Indicators and thresholds

$$\mathcal{I}_k\big(t, x(t), u(t)\big) \geq \iota_k$$

# Viability probability

- This is the probability over uncertainty scenarios that, given a decision rule and objectives, the resulting trajectory satisfying the constraints at all times

$$\Pi(\widehat{u}, \iota_1, \ldots, \iota_K) := \mathbb{P}\left\{ \omega(\cdot) \in \Omega \;\middle|\; \begin{array}{l} x(t_0) = x_0 \\ x(t+1) = G\big(t, x(t), u(t), \omega(t)\big) \\ u(t) = \widehat{u}\big(t, x(t)\big) \\ \mathcal{I}_k\big(t, x(t), u(t)\big) \geq \iota_k \\ k = 1, \ldots, K \\ t = t_0, \ldots, T \end{array} \right\}$$

# The optimality case

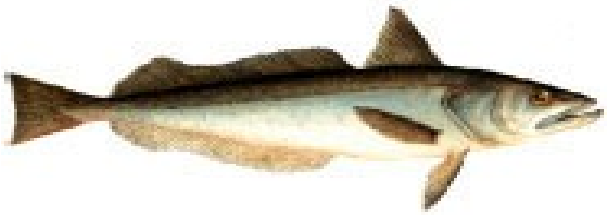
- With “nice” models
  - “Monotonic dynamics”: increases with the stock and decreases with the effort
  - “Biological indicator”: increases with the stock and decreases with the effort
  - “Economic indicator”: increases with the effort and the stock

# The optimality case

- With “nice” models
  - “Monotonic dynamics”: increases with the stock and decreases with the effort
  - “Biological indicator”: increases with the stock and decreases with the effort
  - “Economic indicator”: increases with the effort and the stock
- Optimal management strategy, for given economic and ecological objectives, is a “precautionary management rule”:
  - Harvest only the quantity required to satisfy the economic viability constraint

# The Bay of Biscay Hakes-Nephrops Fishery

(thanks to Claire Macher for the nice pictures)



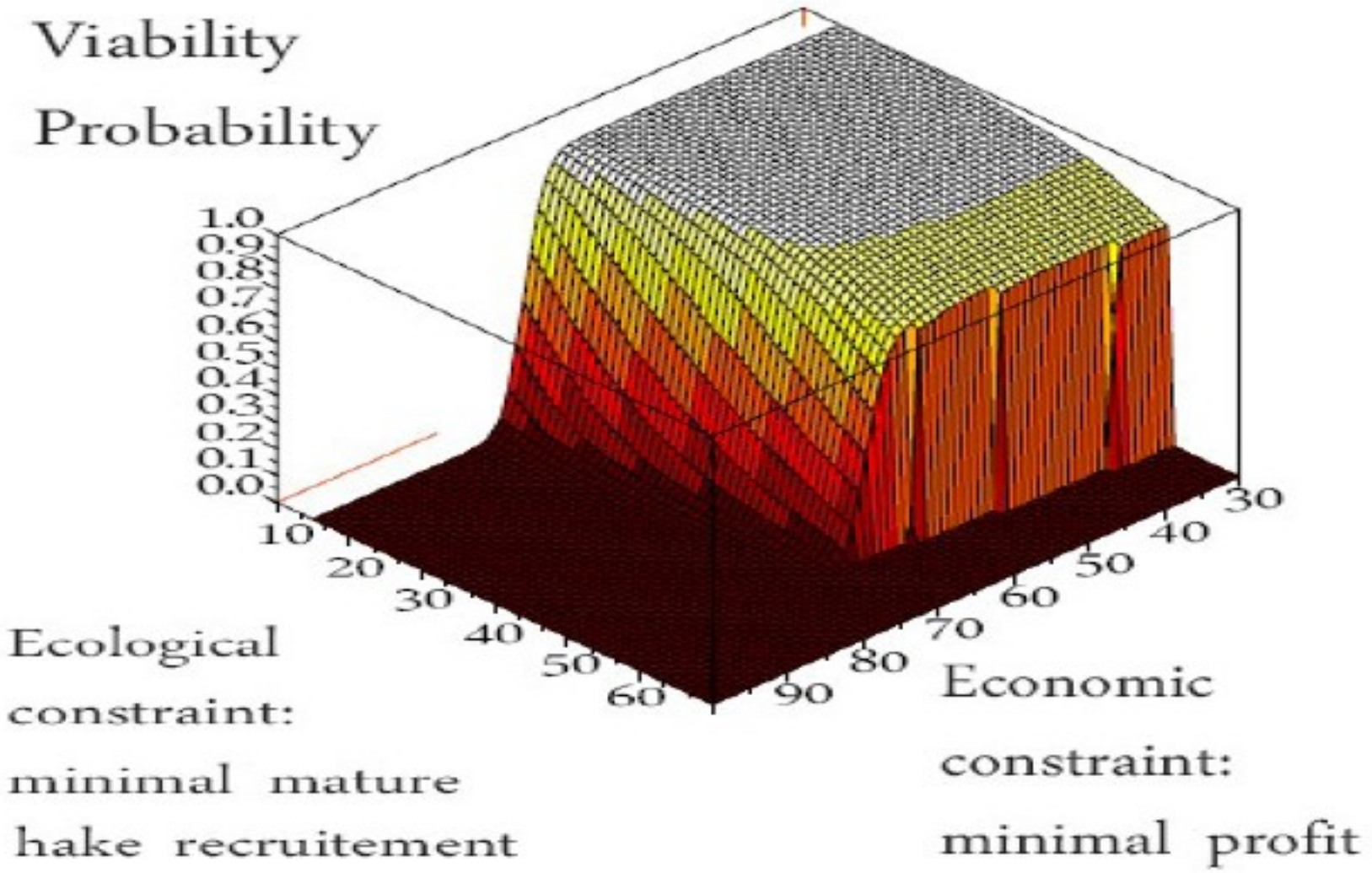
Source: Brenda Guild Gillespie

# Bioeconomic model for the viability analysis of the Bay of Biscay Hakes-Nephrops Fishery

- 2 species: Hake and Nephrops
- Uncertainty in recruitment
- Age-group dynamics
- 2 fleets: Hake and Nephrops
- Ecosystemic interactions :
  - The Nephrops fishery has an impact on the Hake fishery (juvenile hakes as bycatch)
- Economic indicator: Nephrops fishery's profit
- Ecological indicator: Recruitment in the Hake fishery (age group 4)

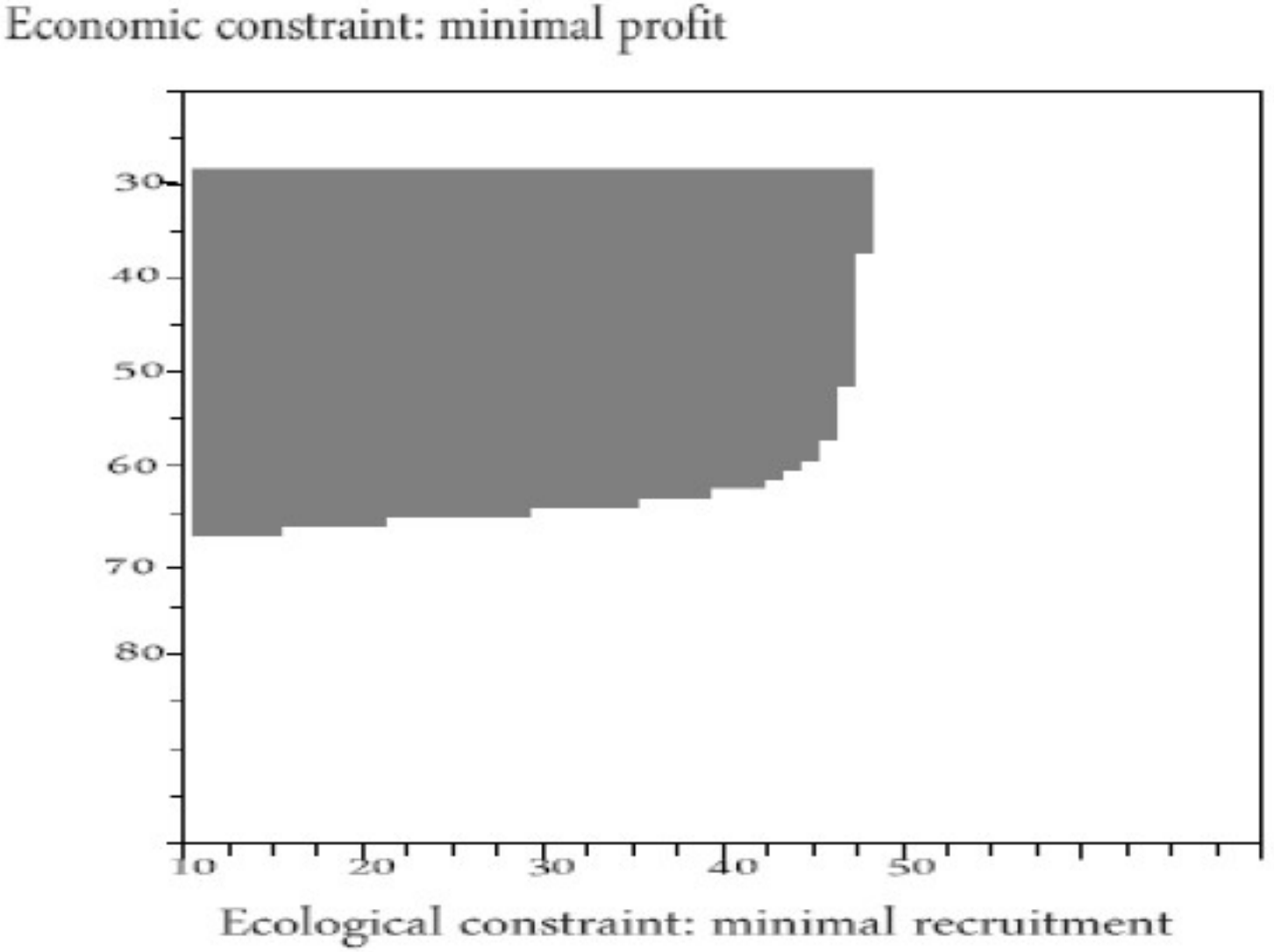
# Results (1/2): Viability probability

Fig. 1: Viability probability for a range of sustainability objectives $\pi_{min}$ and $N^{h}_{min}$



# Results (2/2): Objectives achievability

Fig. 2: Sustainability objectives that are achievable with a probability greater than 0.9



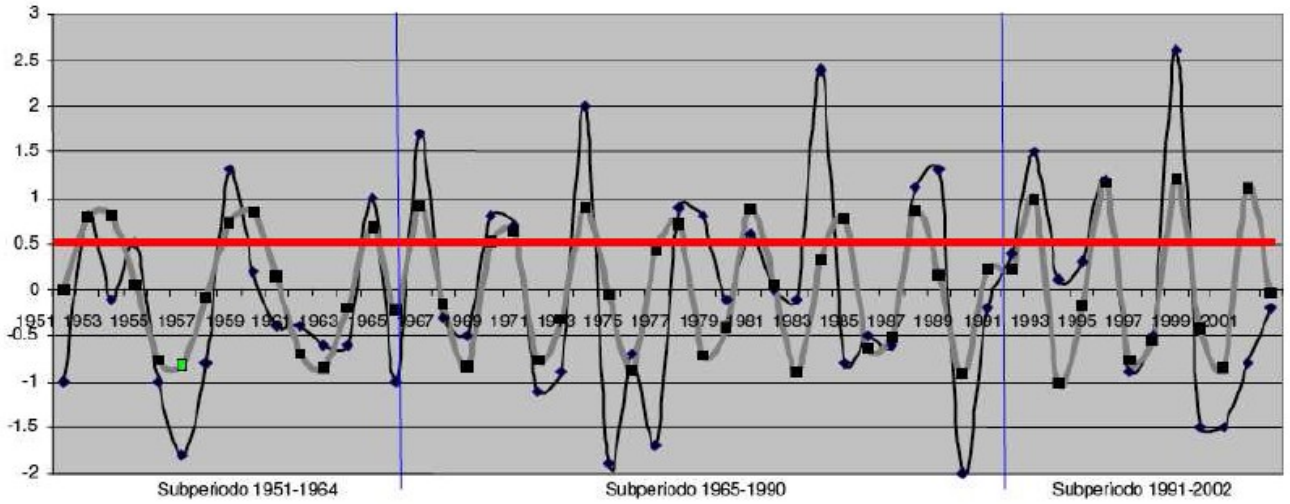
# The sub-optimality case

- What can we do when it is not possible to define the management rule which maximizes the viability probability?

- We can compare given management strategies as in the Management Strategy Evaluation approach
  - Constant quotas
  - Constant effort

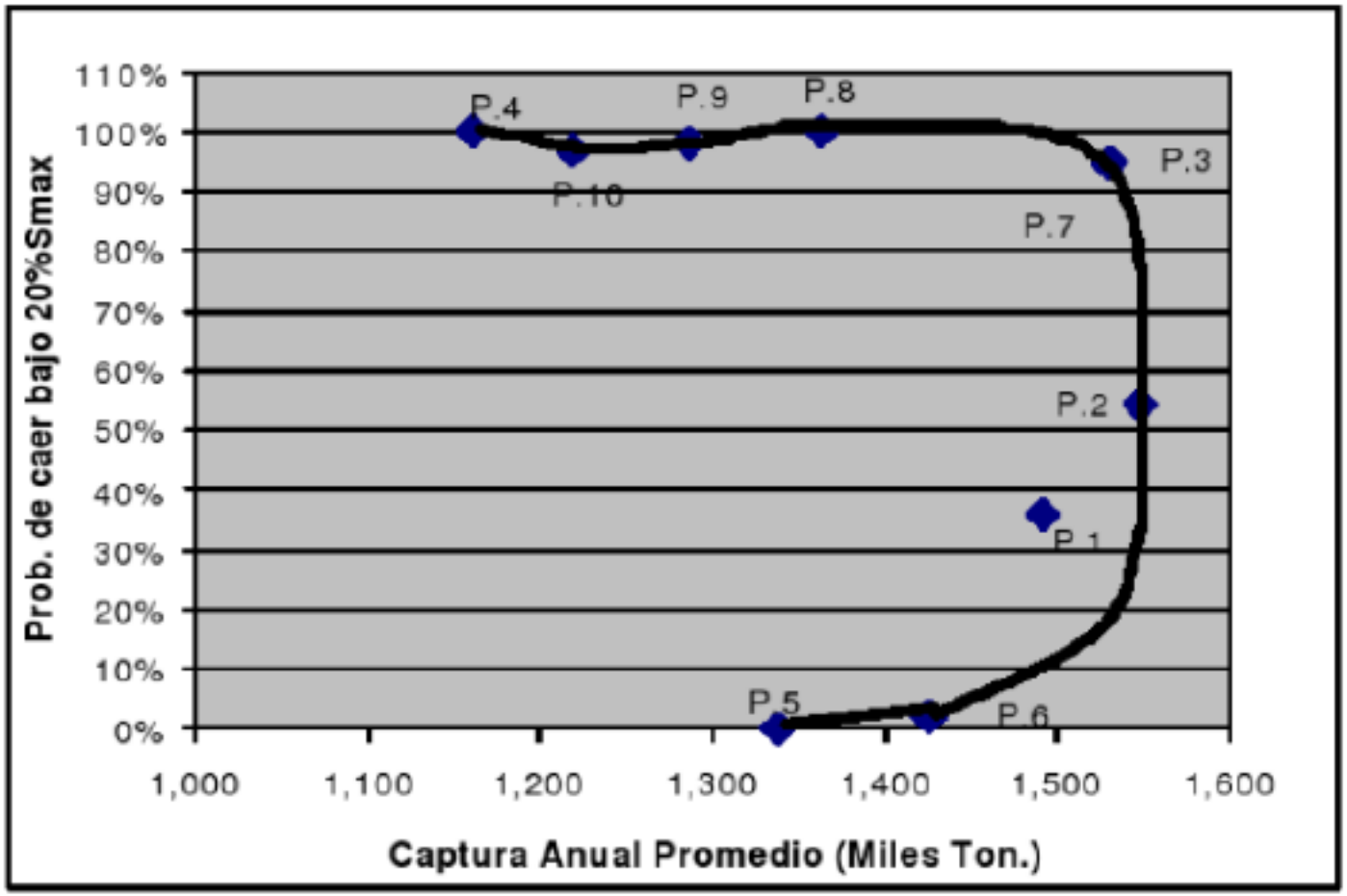
# The Chilean Jack-Mackerel Fishery

- El Niño uncertainty impacts recruitment



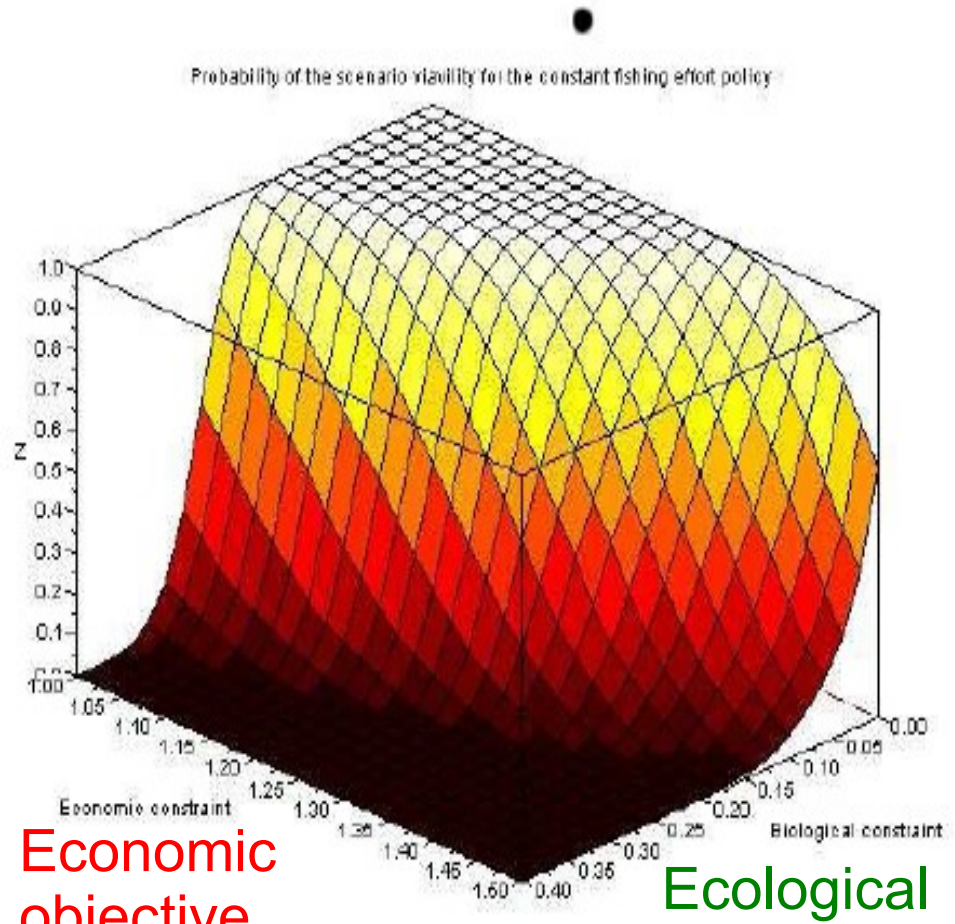

- Age-structured model with Ricker recruitment function (w.r.t. SSB)
- Economic objective: Profit maximization
- Ecological objective: Stock preservation

# Management Strategy Evaluation



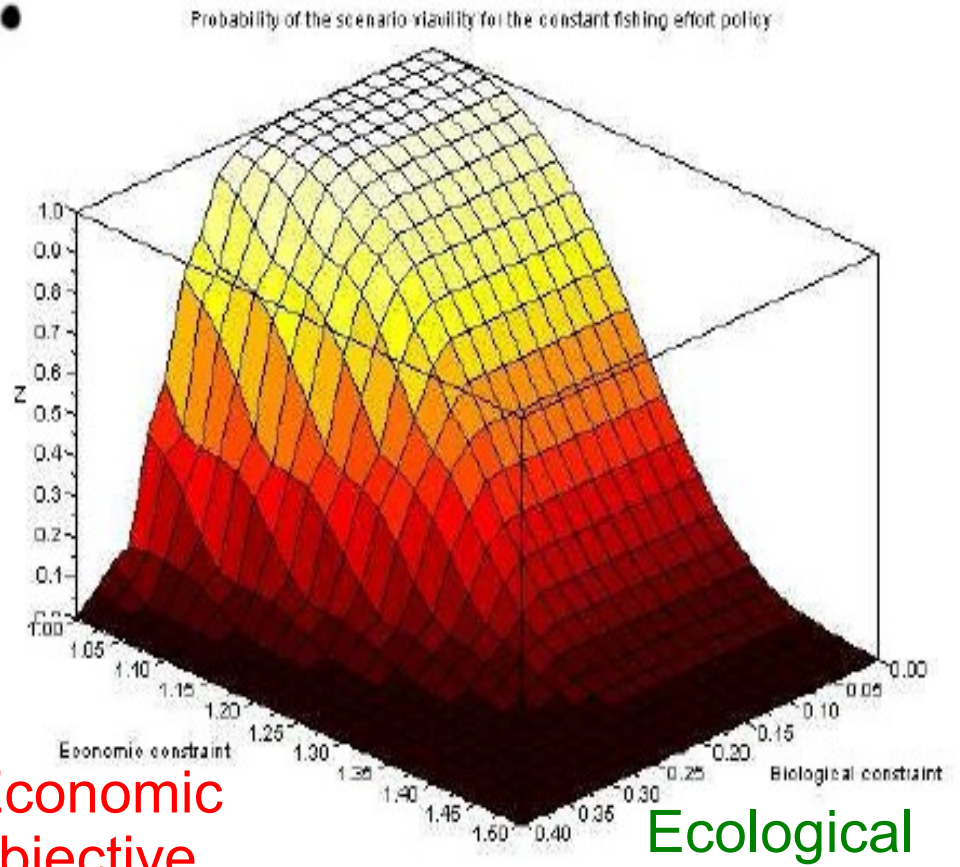
# Constant quotas vs. constant effort

VIABILITY PROBABILITY




Economic objective

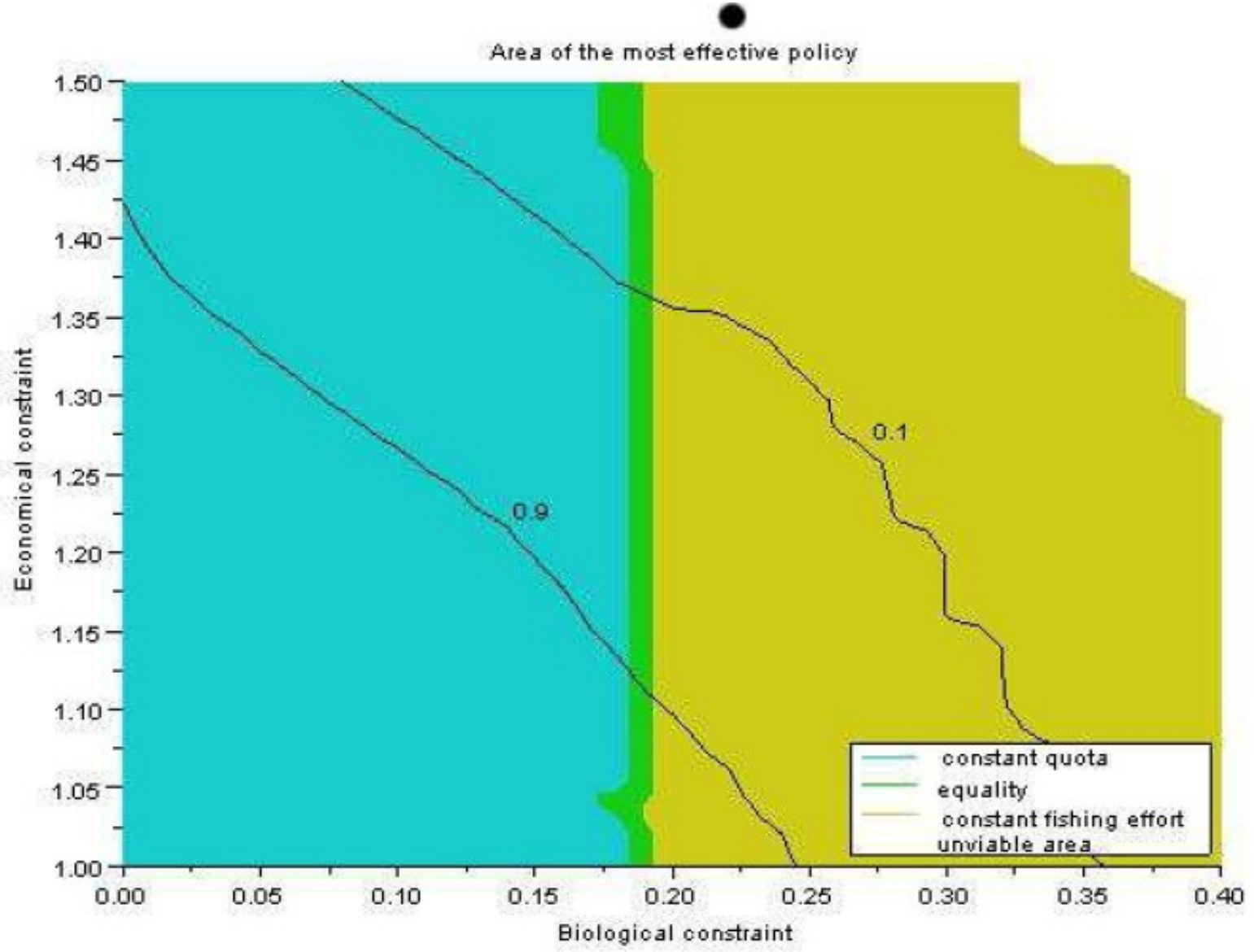
Ecological objective




Economic objective

Ecological objective

# Constant quota vs. Constant effort



# Conclusion

- The stochastic viability approach
  - Provide of optimality and sub-optimality in a multicriteria framework
  - Makes it possible to rank MPs w.r.t. their viability probability

- Remark: Dimensional curse can be avoided by focusing on key interactions within exploited ecosystems (extension of single species indicator approach, as argued by A. Charles, 2005)

# Thank you for your attention

- References:
  - De Lara & Martinet (2009) 'Multi-criteria dynamic decision under uncertainty: A stochastic viability analysis and an application to sustainable fishery management', Mathematical Biosciences 217:118-124
  - Martinet, Peña, Ramirez & De Lara (2009) 'Risk and sustainability: assessing resource management procedure', Work in progress.
  - Martinet, Thébaud & Doyen (2009) 'Sustainability of a fishery: a stochastic viable analysis of trade-offs between economic and ecosystemic indicators', Work in progress.

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